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vations of this kind. It consisted in selecting a few small stars in the immediate vicinity of the variable object, and employing them as standards of comparison for the purpose of ascertaining the quantity of light which the star emitted while in the course of passing through its successive stages of brightness. It is manifest that the results obtained by this method would be independent of the state of the atmosphere, since any fluctuation arising from this cause would equally affect both the variable star and the star of comparison. It would be, of course, indispensable to its successful application that the stars selected for comparison should be of different magnitudes, and that their light be found by attentive observation to be sensibly steady.

The Hypothesis of Otto Struve respecting the Gradual Increase of Saturn's Ring, discussed with reference to the Manuscripts of Huyghens and the Accuracy of modern Observations. By Professor Kaiser.*

In this memoir Professor Kaiser examines the grounds of the hypothesis recently advanced by M. Otto Struve relative to the existence of a continual variation of *Saturn's* rings. According to that hypothesis, while the diameter of the planet and the exterior diameter of the outer bright ring have constantly preserved the same values, the interior diameter of the inner bright ring has been constantly diminishing; consequently, the system of bright rings is gradually increasing in breadth, and thereby approaching nearer and nearer to the body of the planet.

The author, after some preliminary remarks, gives an exposition of the numerical results upon which M. Otto Struve founded his hypothesis. Assuming that the exterior diameter of the outer ring has always exceeded the diameter of the planet by 22″·20, M. Struve found for the breadth of the rings, the breadth of the dark space included between them and the planet, and the ratio of the latter of these two quantities to the former, the results contained in the following table:—

Observer.	Year.	Breadth of Rings. ″	Breadth of Dark Space. ″	Breadth of Dark Space. / Breadth of Rings.
Huyghens	1657 ..	4·6 ..	6·5	1·41
Huyghens and Cassini	1695 ..	5·1 ..	6·0	1·18
Bradley	1719 ..	5·7 ..	5·4	0·95
Herschel	1799 ..	5·98 ..	5·12	0·86
W. Struve	1826 ..	6·74 ..	4·36	0·64
Encke and Galle ..	1838 ..	7·06 ..	4·04	0·57
O. Struve	1851 ..	7·43 ..	3·67	0·49

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* De Stelling van Otto Struve omtrent het breeder worden van den Ring van Saturnus getoetst aan de handschriften van Huijgens en de naaukeurigheid der latere waarnemingen door F. Kaiser. (Verslagen en Mededeelingen der Koninglijke Akademie van Wetenschappen. Deerde Deel, Amsterdam, 1855.)

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The author remarks that of the seven determinations contained in the preceding table there is not one which does not tend to support the hypothesis of M. Otto Struve, that during the last two centuries the ring has been continually increasing in breadth. He adds, however, that if the probable errors of these determinations should exceed in magnitude the variations which they are supposed to undergo, any conclusion deduced from them must be considered as doubtful. It is true that the previous researches of M. Otto Struve afford no reason to suppose that he would have allowed his judgment to be warped by any equivocal considerations; but still it cannot be denied that a preconceived idea may lead the most candid inquirer astray in his reasoning. Moreover, the proneness to exaggerate the accuracy of observations is so common that M. Otto Struve may not impossibly have been led to commit a similar mistake in the course of his investigation.

The author accordingly proceeds to examine the method by which M. Struve arrived at the results contained in the foregoing table. He remarks that hitherto no astronomer had formally called in question the hypothesis of M. Struve, but that several early drawings of the planet had been cited, which, in so far as they might be considered trustworthy, appeared in some instances to confirm the truth of that hypothesis. He is of opinion, however, that these drawings were in all probability founded on the descriptions and drawings given by Huyghens, who devoted more attention to the appearance of the planet than any of his contemporaries, and that, consequently, they cannot be considered as furnishing any independent confirmation of the measures of the Dutch astronomer. Perhaps there may not seem sufficient grounds for the opinion here expressed by Professor Kaiser. There can hardly be any question, however, with respect to the inadequacy of those early sketches in deciding a question of such delicacy as that raised by the researches of M. Otto Struve.

Alluding to the wishes expressed by the Council of this Society that the object-glasses of Huyghens, in the possession of the Royal Society, should be remounted for the purpose of ascertaining the exact influence of irradiation in observations with them, the author has the following remarks:—

"Although I quite agree in the desirableness of ascertaining with greater precision the meaning which ought to be attached to the words of Huyghens, still I cannot refrain from expressing my surprise at the way in which the Royal Astronomical Society of London have proposed to effect this object. The object-glasses of Huyghens, which are preserved by the Royal Society of London, have focal distances of 210, 170, and 120 feet. These glasses were not executed by Christian Huyghens, as has been erroneously supposed in foreign countries, but by his brother Constantine Huyghens. They are all much larger than the largest of the glasses with which Christian ever observed the planet *Saturn*, and more especially they are very large compared with the glasses with which he executed the observations which have formed the

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groundwork of M. Struve's theory. Whenever, then, the Saturnian system is observed with the glasses in the possession of the Royal Society, it ought certainly to exhibit a different appearance from that indicated by the descriptions and drawings of Huyghens, even although it had not in reality undergone any change, and therefore are such observations incapable in the slightest degree of deciding the question with respect to the variability or constancy of *Saturn*."

It is plain from the foregoing passage that the author labours uuder a totally erroneous impression with respect to the object which was proposed to be effected by the remounting of one of the Huyghenian object-glasses, in the possession of the Royal Society. It was, we need scarely mention, for the purpose of ascertaining the effect of irradiation, not upon Huyghens' observations of *Saturn* and his rings, but upon those of Bradley, which were executed with one of Huyghens' telescopes belonging to the Royal Society, that the idea of remounting the object-glass employed in those observations was at one time entertained in this country.*

Huyghens, in all his works, has only alluded twice to the dimensions of *Saturn's* rings, and on both occasions in very brief terms. In his *Systema Saturnium*, published in 1659, he remarks that the space between the ring and the body of the planet is equal to, or even a little greater than, the breadth of the ring ("latitudinem spatii inter annulum globumque *Saturni* interjecti æquare ipsius annuli latitudinem vel excedere etiam)." His next allusion to the subject is contained in his *Cosmotheoras*, which was first published in 1698. On this occasion he asserts that the space between the ring and the planet is exactly equal to the breadth of the ring ("vacuum spatium inter utrumque interjectum eandem quam annulus latitudinem habebit").

The mode by which M. Otto Struve determined the ratio of the interval between the ring and the planet to the breadth of the ring in both these instances is worthy of remark. According to his original assumption, the distance from the edge of the planet's disk to the exterior edge of the ring amounted constantly to 11″·1. If the dark space between the planet and the ring *appeared* exactly

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* The expression of the author, "in order to ascertain what aspect *Saturn*, in his present condition, would have exhibited to Huyghens," ("obdat men, omtrent het voorkomen waaronder *Saturnus* in zijn' tegenwoordigen toestand door Huijgens zoude zijn waargenomen, zoude worden ingelicht") does not convey the exact meaning of the words used in the Annual Report of the Council of this Society, which were these :—"It appears, however, that to give these observations their full value, it will be desirable that observations on *Saturn* be repeated with Huyghens' object-glasses, still preserved, it is understood, in the care of the Royal Society" (*Monthly Notices*, vol. xiii. p. 129). The Huyghenian object-glass which Bradley employed in his observations of *Saturn* had been lent by the Royal Society to his uncle Pound; it had a focal length of 123 feet. This was the object-glass which the British Association at one time contemplated re-mounting, for the purpose of testing Otto Struve's theory, but the idea appears to have been subsequently abandoned. (See Brit. Assoc. Rep., 1852, p. xxxiii.; Rep. 1853, p. xxiv.) It may be remarked, that the oversight which the author has committed in this instance does not affect any of the conclusions at which he has arrived in the course of his discussion.

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equal to the breadth of the ring, it must *in reality* have exceeded the latter quantity, in consequence of the effect of irradiation, and, therefore, must be somewhat greater than 5″·55. Supposing the irradiation to amount to 0″·5, M. Struve hence concluded that in 1657, when the breadth of the space between the planet and the ring was considered by Huyghens somewhat to exceed the breadth of the ring, the former of these spaces must have measured *very nearly* 6″·5, and the latter 4″·6; and he fixes upon these as the definitive values for the epoch to which they refer, whence he derives 1·4 for the ratio of the two quantities. With respect to the second epoch, the reasoning of M. Otto Struve is certainly objectionable. Proceeding upon the assertion of Huyghens, that the space between the planet and the ring, instead of being greater than the breadth of the ring, as it was in 1657, was now exactly equal to the latter, he hence concludes that the breadth of the dark space must, therefore, be less than 6″·5. But, he remarks, it must exceed 5″·5, on account of irradiation. The mean of these two quantities is 6″, which he lays down as the breadth of the dark space for the second epoch. This leaves 5″·1 for the breadth of the ring, whence he obtains 1·18 for the ratio of the two quantities corresponding to the year 1695.*

The author maintains that the reasoning by which these results have been deduced cannot stand the test of strict discussion. With respect to irradiation, he is of opinion that it depends upon the eye of the observer, that its effects are of a vague and contradictory character, and that the safest course generally is to take no account of its influence in astronomical observations. We extract the following passage from his remarks upon this subject:—

"Granted, however, that an irradiation exists, in virtue of which luminous objects appear enlarged when projected upon a dark ground, still it by no means follows that irradiation must cause dark objects projected upon a light ground to appear too small. If we assume that the amount of irradiation is the same, whatever be the magnitude of the dark object, we should then fall

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* It will be seen that in determining the breadth of the dark space for the first epoch, M. Otto Struve adopted a *definite* value of irradiation; but he took no account of the remark of Huyghens, that the dark space *somewhat exceeded* the breadth of the ring. On the other hand, his investigation of the breadth of the dark space for 1695 is founded upon an *indefinite* value of irradiation and upon the supposition that the words of Huyghens, "vel excedere etiam," *were duly taken into account in determining the value of the space for* 1657. The results for the two epochs are not, therefore, comparable: first, because a similar view of the influence of irradiation was not taken in both investigations; secondly, because the principles of ratiocination in the two cases are in contradiction with each other. In fact, if the value of irradiation be assumed equal to 0″·5 in both cases, the breadth of the dark space must have been somewhat greater than 6″·5 in 1657, and must have been exactly equal to that quantity in 1695, or, in other words, the ratio of the two quantities would have amounted to a little more than 1·41 at the former of these epochs, and to exactly 1·41 at the latter epoch, instead of 1·41 and 1·18 respectively, according to M. Otto Struve.

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into the absurd conclusion that very small dark objects are changed by irradiation into objects of a greater degree of brightness than that of the ground upon which they are projected, and no relation between the magnitude of the object and the quantity of irradiation can be assumed so long as we possess absolutely no proof of the existence of such a relation."

The author then proceeds to remark that the observations of Huyghens show that dark objects when viewed by him did not appear diminished by irradiation to the extent of 0″·5. It appears from his Journal that he repeatedly observed the shadow of one of *Jupiter's* satellites upon the body of the planet. In general, the satellites subtend an angle of 1″, and the apparent diameter of the shadow in any case must, consequently, be somewhat less than that quantity. Upon this ground the author contends that if the effects of irradiation had amounted to 0″·5, the shadows of the satellites must have been totally invisible to Huyghens,—a result which is at variance with the records of his Journal. He concludes that the safest course is to reject all consideration of the influence of irradiation, and, assuming with M. Otto Struve that in 1657 the dark space between the planet and the ring appeared to Huyghens to be equal to the breadth of the ring, the ratio of the two quantities would be not 1·41, but simply 1·0. He, moreover, maintains, upon the ground of the unsatisfactory nature of M. Otto Struve's reasoning, with respect to the influence of irradiation upon the observations of 1695, that the ratio of the dark space to the breadth of the ring for that epoch must also be considered as equal to unity.

The author next gives an account of certain drawings of *Saturn* and his rings which have been found among the manuscripts of Huyghens, preserved in the University of Leyden. They are merely rough representations which Huyghens sketched out with his pen in one of his observation-books.* The earliest drawing refers to the appearance of the planet on the 27th of December, 1657; the latest to his appearance on the 24th of August, 1693. The total number of drawings amounts to twenty-three. Selecting those that appeared most worthy of confidence, the author carefully examined them for the purpose of ascertaining what light they were calculated to throw upon the subject of discussion. The following are the values of the ratio of the dark space to the breadth of the ring which he obtained for four distinct epochs by actual measurement of the drawings:—

	$\frac{\text{Breadth of Dark Space}}{\text{Breadth of Rings.}}$
1657, Dec. 27	0·72
1675, Dec. 8	0·95
1682, Oct. 16	1·01
1693, Aug. 24	1·24

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* Professor Kaiser's paper contains copies of three of these drawings, referring severally to the appearance of the planet in the years 1657, 1675, and 1693.

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It would appear from these results that during the lifetime of Huyghens the ring, instead of gradually increasing in breadth, was, on the contrary, growing narrower. The author, however, is of opinion that the observations of the Dutch astronomer are incapable of leading to any trustworthy conclusions on the subject.

"A mere comparison of the drawings of Huyghens with the most recent measures cannot," says he, "decide anything respecting the variability or constancy of the rings of *Saturn*. The latest measures of *Saturn's* rings, namely, those which have been executed by Mr. Main at Greenwich, in the beginning of the year 1853, assign 0·82 for the ratio of the dark space to the breadth of the ring. The drawings of Huyghens assign to this ratio all values included between 0·72 and 1·24. We might, therefore, by a comparison of the observations of Huyghens with those of recent times, make out that the ring was gradually becoming broader or narrower, according as we found either hypothesis convenient for our purpose; and we shall, therefore, do best by considering the observations to be totally unsuitable for an investigation such as that undertaken by M. Otto Struve."

After an examination of Bradley's and Herschel's observations of *Saturn* and his rings, the author next considers the modern observations, namely, those of W. Struve, Encke, Galle, Bond, Otto Struve, and Main. On the observations of the latter, which were executed in 1852–3, the author has the following remarks:—

"These measures have now furnished a result which for once is at variance with the hypothesis of Otto Struve. They assign 0·80 for the ratio of the dark space to the breadth of the ring, a value which exceeds the ratio obtained by W. Struve, as much as the ratio of Otto Struve falls below the latter. If, then, the measures of Otto Struve demonstrate that since the year 1826 the ring of *Saturn* has sensibly increased in breadth, the observations of Main, on the other hand, indicate an equal diminution of breadth for the same period. If we assume that for the smaller, and perhaps less perfect telescope of Main, the amount of irradiation is much greater than for the telescope of Pulkowa, the measures would be still more unfavourable to the hypothesis of Struve. Admitting that the irradiation in Main's telescope amounted to merely a quarter of a second, we should then obtain 0·95 for the ratio of the dark space to the breadth of the ring, a result agreeing with that which M. Struve deduced from the measures of Bradley, executed 134 years earlier, and also with the ratio indicated by the most complete drawing of *Saturn*, contained in the Journal of Huyghens, which was written 177 years previously. From the discordance between Otto Struve and Main we may form an opinion of the degree of confidence to which the measures and estimations of the seventeenth and eighteenth centuries are entitled."

The author concludes by asserting that there exists no reason

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whatever for supposing that the compound ring of *Saturn* is gradually increasing in breadth.*

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* Professor Kaiser's paper contains a variety of critical remarks upon the advantages and defects of the heliometer, the wire micrometer, and the double-image micrometer, in measures such as those relating to *Saturn's* rings. He is inclined to prefer the modified form of Airy's double-image micrometer suggested by Valz (*Monthly Notices*, vol. x. p. 160), and, with the view of testing the justness of the conclusion at which he arrived, he has ordered one of such micrometers of Mr. Simms, which he purposes applying to the telescope of the Leyden Observatory.

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